**Interactive comment on "Bipolar long-term high temporal resolution broadband measurement system for incoming and outgoing solar UV radiation, and snow UV albedo, at Sodankylä (67$^o$N) and Marambio (64$^o$S)" by O. Meinander et al.**

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**Authors' response to the review of the Anonymous Referee #3**

We thank Referee#3 for giving critical review comments on our GID-manuscript of *"Bipolar long-term high temporal resolution broadband measurement system for incoming and outgoing solar UV radiation, and snow UV albedo, at Sodankylä (67$^o$N) and Marambio (64$^o$S)"* Our respond to each remark of the Referee#3 is given here below.

First, due to the critical comments of Referee#3, we will in our reply (more detailed here below) suggest some new unpublished quantitative results that we consider relevant for any data user. We will give some example figures to demonstrate some of the options of such results.

Secondly, we'd like to bring out that all the three reviewers gave the same comment on the second section. The common comment was to shorten and summarize the contents of the second section, and rather use it as an introductory summary. We therefore suggest to follow this advice, and to shorten the contents of the summary (named as summary, instead of "review" used in the submitted manuscript) to 1-2 chapters, and to include this in the Introduction-section. The literature references of our earlier work are given for the benefit of any future data user. This fact we suggest also to be more clearly stated in the suggested revised version of the manuscript. In addition, we suggest to include a more detailed theoretical background in the Introduction, with key equations to explain the data, and also including some quantitative error and uncertainty estimates of these data. Some of these will be suggested here, and some of these are explained in our replies to Referee#3 comments (below later).

For the U-shape of the albedo signal, we suggest to add the following Equation of Briegleb et al. (1986) to explain the U-shape of the detected albedo:

$$R(\mu) = R_0 \frac{(1+d)}{1+2d\mu}$$

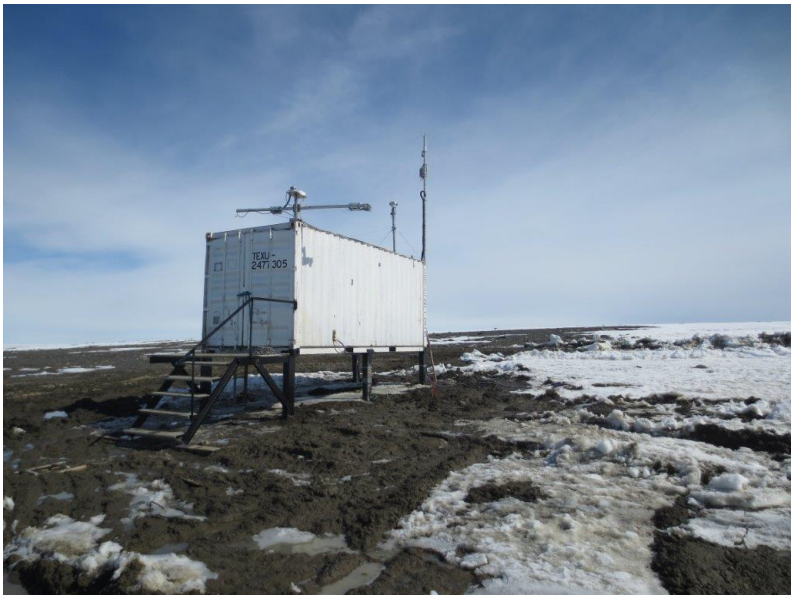
where μ is the cosine of the SZA, and $R_0$ is the reflectivity for μ = 0.5 as given in their Table 2, and $d$ is an empirical parameter.

Reference:

Briegleb BP, Minnis P, Ramanathan V, Harrison E. Comparison of Regional Clear Sky Albedos Inferred from satellite Obervations and Model Computations. Journal of Climate and Applied Meteorology, 25, 214-, 1986.

This Equation we think can be of use for the albedo data user to understand the SZA dependency of the albedo data.

Also, a new photograph (below) is suggested to be inserted in the revised manuscript. The photo shows the horizontal pole where the downward sensor will be/is attached.




In addition, related to measurement errors and uncertainties, we suggest to add 1-2 new edited sentences referring to Meinander et al. (2009) where we said (based on calculations presented by one of the co-authors, prof. Seckmeyer, Germany): *" the measured angular responses of the two Arctic SL-501 biometers were used to quantify uncertainties due to cosine error. Integrating incoming radiances over the whole hemisphere, and assuming isotropic distribution of the diffuse scattered light, we calculated an error of the incoming scattered light contribution of 0.5 % and 3.2 % for the up-welling and down-welling sensor, respectively."* Related to the measurement errors and uncertainties, we also suggested in our replies to Referee#1 and Referee#2 to include other new text in the suggested revised version of the manuscript. We will not repeat these here, as they are available for Referee#3 at http://www.geosci-instrum-method-data-syst-discuss.net/gi-2015-31/.

Finally, we'd also like to bring out the fact that our paper is aimed at GI, not elsewhere. The aims and scopes of the paper are defined as follows (http://www.geoscientific-instrumentation-methods-and-data-systems.net/about/aims_and_scope.html):

"Geoscientific Instrumentation, Methods and Data Systems (GI) is an open-access interdisciplinary electronic journal for swift publication of original articles and short communications in the area of geoscientific instruments. It covers three main areas: (i) atmospheric and geospace sciences, (ii) earth science, and (iii) ocean science. A unique feature of the journal is the emphasis on synergy between science and technology that facilitates advances in GI. These advances include but are not limited to the following:

- concepts, design, and description of instrumentation and data systems;
- retrieval techniques of scientific products from measurements;
- calibration and data quality assessment;
- uncertainty in measurements;
- newly developed and planned research platforms and community instrumentation capabilities;
- major national and international field campaigns and observational research programs;
- new observational strategies to address societal needs in areas such as monitoring climate change and preventing natural disasters;
- networking of instruments for enhancing high temporal and spatial resolution of observations.

GI has an innovative two-stage publication process involving the scientific discussion forum Geoscientific Instrumentation, Methods and Data Systems Discussions (GID), which has been designed to do the following:

- foster scientific discussion;
- maximize the effectiveness and transparency of scientific quality assurance;
- enable rapid publication;
- make scientific publications freely accessible."

We argue that our paper includes from these the following:

- **concepts, design and description of instrumentation and data systems** (here: bipolar SL-501 UV radiation measurements of incoming and outgoing solar radiation),
- **some of the calibration and data quality assessment and uncertainty** (here: we refer to the listed "challenges" of the submitted version, now suggested to be changed to more quantitative presentation of calibration, data quality and uncertainty, as presented in our reply to Referee#2 (ref. our reply to Referee#2 at http://www.geosci-instrum-method-data-syst-discuss.net/gi-2015-31/),
- **observational research programs** (here: WMO GAW Marambio and GAW Sodankylä; and Antarctic research under the FINNARP program),

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### *A) General comments*

***Referee#3:***

***"The manuscript by Meinander et al. describes a system for the measurement of incoming and outgoing solar broadband UV radiation at two polar sites, i.e. Sodankylä and Marambio. After a general introduction, the measurement sites, the working principles, the data collection system, the calibration and the biggest challenges in such measurements are illustrated. Starting from Sect. 3, the authors list the major findings already reported in their previous publications. Although the paper addresses very relevant scientific questions, its declared focus is "not to publish the existing data nor their scientific analysis", as the authors themselves acknowledge, and the manuscript does not present any new finding. "***

**Author's reply:**

To start with, we thank Referee#2 for saying that the paper addresses very relevant scientific questions.

We agree with Referee#3 that it was our statement in the submitted manuscript that our focus was ***"not to publish the existing data nor their scientific analysis".*** We agree that our submitted manuscript did not contain new data nor their scientific analysis.

To publish the incoming and outgoing measurement data with QA/QC and data analysis would require work similar to described in two ACP papers of Meinander et al. 2008 (http://atmos-chem-phys.org/8/6551/2008/acp-8-6551-2008.pdf) and Meinander et al. 2013 (http://www.atmos-chem-phys.net/13/3793/2013/acp-13-3793-2013.pdf), which both, in our opinion, show that there is a need for separate paper for publishing the data sets. (Data plots of raw data of incoming and outgoing solar radiation we suggest not to be published within this manuscript.)

However, as will be explained more detailed here later, we have some new unpublished measurement data, e.g., on spectral and cosine responses of the sensors, which in our opinion could be useful for any data user, and could be published as part of this manuscript.

Referee#3 then continues that " ***the manuscript does not present any new finding".*** To this we on the one hand partly agree, but on the other hand also partly disagree. First, we need to consider what is meant by "new finding". If finding refers to presenting new data and their analysis, it is true

that our submitted manuscript did not contain any new finding. This is because the focus of this paper is to present the measurement systems, and our experiences using them, for the benefit of a future data user. This is because we have decided to give the data out in data basis outside our own institutes. However, for the revised manuscript we will here below suggest new findings and quantitative data which are relevant to the paper and to data users, as well.

As background, we'd also like to bring out that the preparation of this manuscript was the first time that the people who had worked for these bipolar measurements in Finland and in Argentina, including Marambio and Sodankylä station technical personnel, gathered their experiences and work together. This certainly is of value, and this to take place is actually thanks to the existence of the journal GI. Hence, our paper aims for GI, not elsewhere. Keeping these aims and scopes of GI in mind, we argue that our paper includes from these the following (as said in the very beinning of our reply): **concepts, design and description of instrumentation and data systems** (here: bipolar SL-501 UV radiation measurements of incoming and outgoing solar radiation); **some of the calibration and data quality assessment and uncertainty** (here: we refer to the listed "challenges" of the submitted version, now suggested to be changed to more quantitative presentation of calibration, data quality and uncertainty, as presented in our reply to Referee#2 (ref. our reply to Referee#2 at http://www.geosci-instrum-method-data-syst-discuss.net/gi-2015-31/); **observational research programs** (here: WMO GAW Marambio and GAW Sodankylä; and Antarctic research under the FINNARP program). Therefore, we suggest more emphasis on these aims in the suggested revised manuscript. Additionally, we suggest new data to be included, as demonstrated in the figures and text here below.

As we stated already in the beginning of our reply to Referee#3, our own earlier publications (called as review in our submitted version) will be shortened and can be considered as a summary of a previous work, aimed to benefit any data user in the future. Therefore, such a summary can be of value, too.

***Referee#3 (continued):***

> ***"Sections 1, 2.1.1, 2.2, 2.4, 2.5 and most of Sect. 3 are fundamentally quoted from Meinander et al., 2008; the rest of Sect. 3 and Sect. 4.1 are taken from Meinander et al., 2009, 2013 and 2014, respectively. "***

**Author's reply:**

We agree this was the case in the submitted version, but this is not the contents of the revised version. In the revised version these are shortened, summarized and included in the Introduction, as suggested by Referee#3.

***Referee#3 (continued):***

> ***The only new addition to the present manuscript is the description of the Antarctic Marambio Base and its instrument (which is, however, similar to the one employed in Sodankylä and already described by Meinander et al., 2008 in detail).***

**Author's reply:**

We thank the referee for this point and agree that Marambio measurement description has not been published previously.

***Referee#3 (continued):***

> ***Honestly, I cannot find any reason to publish the manuscript in GI, unless relevant new findings are added to the text. In that case, Sects. 3-4 could be summarised to compose a sound introduction of a substantially new paper.***

**Author's reply:**

We thank Referee#3 for this very critical comment. We would suggest to include the summarized sections 3-4 in the Introduction as suggested by Referee#3 here.

We have seriously considered the Referee#3 comment saying "… ***unless relevant new findings are added to the text"***. As described below, including our reasoning, we'd like to suggest to include some new unpublished measurement data, related to the sensors and the measurement environemtn, in the revised manuscript, due to the comment of Referee#3.

Such relevant new findings that could be considered to be presented in the context of describing the measurement systems, and without presenting the data or its analysis (as it is not the scope of this paper, where we aim to describe the measurements could consist of, in our opinion, for example:

1) the previously unpublished measurement results of the cosine and spectral responses of all the sensors used for the measurements since IPY 2007/2008 for Sodankylä, and since 2013 for Marambio. Since 2013, we have always 4 sensors in use at a time. Previously, only one such result in one figure has been published in Meinander et al. (2008) for the 2 sensors used therein (Fig 1. of http://www.atmos-chem-phys.net/8/6551/2008/acp-8-6551-2008.pdf), also shown here below).Such data could either
    a) e.g, consist of all the cases in one figure for cosine responses and other for spectral responses, to show the minimum and maximum changes and the average values; or alternatively
    b) e.g., show more detailed indicating these curves for each used sensor together with a table identifying which sensor was used, where and when.

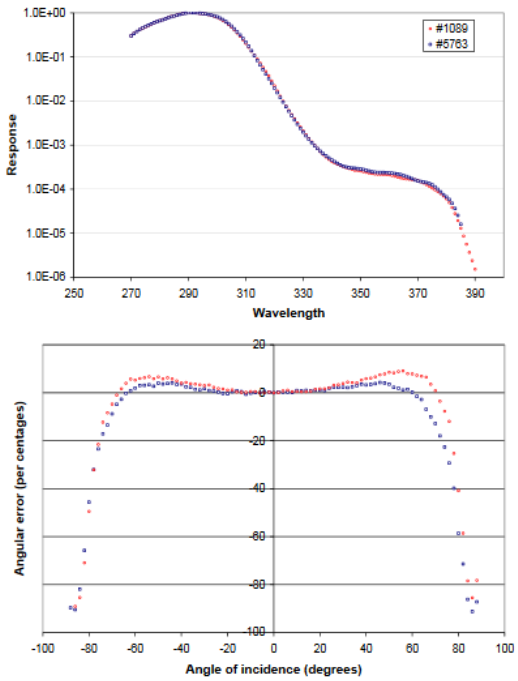
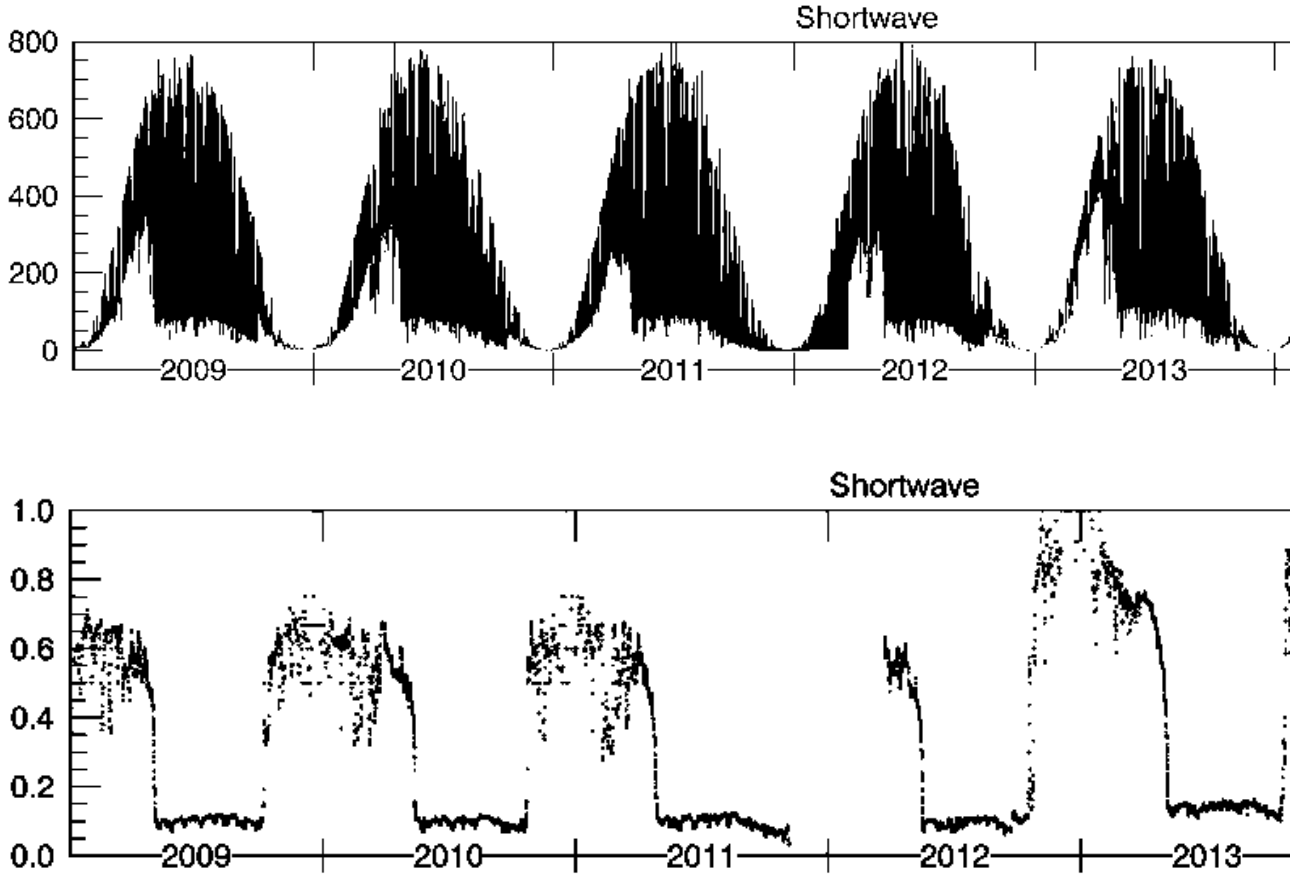



**Fig. 1.** Spectral (above) and cosine (below) responses of the SL501 sensors. Spectral responses are in logaritmic scale showing the maximal differences. The responses of the upward and downward sensors need to be considered when albedo results are interpreted.

The Figure above is adapted from Meinander et al, ACO, 2008. This kind of measurement results on spectral and cosine responses of the SL501 sensors used for Marambio and Sodankylä incoming and outgoing measurements have not been published otherwise, except this one figure for one pair of sensors used in Sodankylä for those data published therein. In Marambio and Sodankylä we have continuously 2 pairs of sensors in use. As a result of the critical comment of Referee#3, we suggest to include and publish in the revised version all the results of the measurements on spectral and cosine responses. These data are new previously unpublished quantitative results that can be of use for a data user.

alternatively/additionally

2) the effect of the tree cut in Sodankylä is evident in the data, and for this purpose we could give out some data showing that for, e.g., the pyranometer maximum values changed from appr. 0.7 to close to 1, after the tree cut. In $W/m^2$ data the change is not as pronounced as when looking at the albedo values.




The two figures above clearly demonstrate the change in the level of the measured albedo after the tree cut in Sodankylä. The albedo field is free of trees. In {$W/m^{2]}$ of incoming and outgoing solar radiation, the shadowing effect is not that pronounced (above), but in albedo data (0-1) the effect is clear. Although the raw data without further analysis and QA/QC procedures is not of value of publishing otherwise, we suggest that for the purpose of showing the shadowing effects of the environment in the boreal zone, this kind of figure can be of use for the data user.

***Referee#3 (continued):***

***The manuscript cannot even be considered, in my opinion, a complete literature review on snow UV albedo, since most of the cited references in the second part of the text only belong to the authors.***

**Author's reply:**

We agree totally, and the word review is not used to describe the shortened summary planned to be included in the suggested revised version of the manuscript.

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**c) Specific comments**

***Referee#3***

***The authors list the main "challenges" of the bipolar UV radiation measurements, but they do not provide an adequate quantification of the resulting overall measurement uncertainty in UV albedo estimates. How large do they expect it to be? Do this kind of measurements still make sense even in presence of large uncertainties?***

**Author's reply:**

We thank Referee#3 for this critical and very relevant comment and question. We refer to our paper of Meinander et al. (2008) saying that "Here, use was made of erythemal UV albedo measurements by broadband SL501 radiometers with similar spectral responses, thus resulting in errors of less than 1% due to differences in the sensors (WMO, 1996). According to Hulsen and Grobner (2007), the typical total uncertainty for SL501 instruments is from 1.7 to 4.3 %. "

We also argue that a transparent presentation on all the uncertainty and error sources of these data are needed in order the data user to use the data successfully used. Also, in the measurements such uncertainties and errors are expected, but not always brought up even in a qualitative way. We presented in our submitted manuscript our sincere overall understanding of all the factors affecting these data, and argue that after knowing all these error sources a successful scientific data usage is possible. In fact, some more discussion on errors and uncertainties is to be included in the suggested revised version as outcome of the comments given by all the three Referees (ref. http://www.geosci-instrum-method-data-syst-discuss.net/gi-2015-31/). Yet, the aim of this paper is not to present more detailed calculations of all the error sources. Many of these would be a subject of its own paper (such references are found in literature, and would be possible to do for these measurements, too).

***Referee#3:***

***l. 70: "this is our first paper to consider the Sodankylä incoming irradiance as an independent data set". Please, explain how this is accomplished in the manuscript. Also, does this mean that no incoming UV irradiance measurements have been previously performed in Sodankylä?***

**Author's reply:**

We need to clarify this in our suggested revised version of the manuscript. We refer here to the fact that our previous papers on this measurement setup for Sodankylä UV albedo on the operational albedo field have presented only results on UV albedo, although the incoming irradiance data could have been used alone, too. In turn, UV irradiance measurements with various instrumentations have been performed in Sodankylä before this measurement setup. We suggest to write this explicitly in the revised version of the manuscript.

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**d) Technical corrections**

**Author's reply:**
We thank Referee#3 for his careful reading and time and effort in giving us these detailed technical corrections needed. We will implement these changes in the suggested revised version of the manuscript, as follows:

**l. 23: "OC/BC": please, define acronyms when used for the first time**: will do that

**l. 28: "Global Atmosphere Watch (GAW)":** ok

**l. 29: "World Meteorological Organization (WMO)":** ok

**l. 31: "International Polar Year (IPY) 2007-2008":** ok

**l. 39-43: at least one citation is needed here**: ok

**l. 53-54: define the "RT" acronym. This sentence is also quite confusing to the reader, since the quantity employed in radiative transfer models is effective albedo, not local albedo. Please, explain how the two quantities are related to each other.:** ok will do that. Referring to Meinander et al. (2008) we have earikler presented that "although the local albedo is affected by the regional albedo, our measurements at a height of 2 m may be considered to represent local albedo. Furthermore, a term "effective local albedo", for instance, could be more descriptive for the albedo quantity derived in our study. The critical question is whether the downwelling radiation field on the snow surrounding the observation point (i.e., in the area where the observed $F(\uparrow)$ originates), differs systematically from $F(\downarrow)$ at the obser-vation point. If not,$F(\uparrow/\downarrow)$ should be an accurate estimate of the local albedo."

**l. 126: add full stop at the end of the sentence:** ok

**l. 135: the SL501 erythemal irradiance is not "calculated" as a spectral integral, since broadband instruments cannot measure a spectrum and convolve it to an action spectrum. Rather, the measurement "represents" the convolution of the solar irradiance spectrum to the spectral response function of the instrument:** we thank the Referee#3 for this comment and will use the word represents.

**l. 144: why "spectral"?** the word spectral" was used, as the response of the sensor is with spectral weighting, although the outcome is one value.

**l. 151: is it essential to always specify "linux-computer"?** thanks, will avoid repeating the word "linux-computer" ultiple times.

**l. 154-160: please, describe only the differences between both systems, do not repeat the common characteristics:** agree and will avoid repeating and remove unnecessary repetition

**l. 176: are the sensors only "temperature controlled" or also "temperature stabilized"?** temperature stabilized is the correct term that will be used

**l. 182: "some data": please, explain what kind of data needed to be excluded:** ok, we suggest to add the following new explanation instead: "to avoid misinterpretation of data, knowledge of the SZA is essential because albedo changes according to the SZA. Again, the cosine response of the sensors affects the measurement results at low solar elevation angles. For data with SZA > 70 degrees, the cosine error is expected to increase dramatically. As most of the irradiance is then diffuse (at 300 nm more than 90%) this declines the impact of low Sun on the measurement results."

**l. 187: could you explain how you cope with the problem of tree shadows?** trees are cut if their shadows reach the albedo field.

**l. 212: "independent data of incoming and outgoing UV radiation": what do the authors mean by "independent"?** We refer to the fact that these are simultaneous measurement that can be used independently, as measured with two sensors separately, one upwards and one downwards. In opposite, some measurement systems are built so that the same sensor is used first down and then turned up, or two fixed optical heads are used one after another but their detector is the same, i.e., the measurement is done first up then down with one detector.

**l. 266: how is "c" defined?** We refer to Meinander et al. (2008) where we presented: *" a) Using the new re-calculated 1-min data for 4 January 2004, we calculated the simple SZA dependent empirical albedo decline, using a simple linear regression approach (albedo = f * SZA). This slope f was calculated to equal with -0.0024; b) Using the original 8 minute-average-data, the decline during the day new slopes (f) were -0.002 for the afternoon data only, and -0.0028 for the whole day. In general, the Antarctic albedo was ranging from ~ 0.96–0.98 (0.98 in 1-min data, and 0.96 using 8-min data) to 0.86, resulting in a decline of ~0.10–0.12 (~10 %) towards the afternoon."*

-> we suggest to add here the description of "*defined using a simple linear regression approach (Meinander et al. 2008)"*

**l. 308:** "The Committee on Earth Observation Satellites (CEOS)": ok

**l. 330-331:** does this consideration apply to both "polar regions" (l. 328): thank you, the Referee#3 is right,it was Antarctic ozone loss in question here. We will add the word "Antarctic".

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Helsinki, 22 June 2016

We have now given our replies to the comments of all the three Referees, as our replies were given first to Referee#1, then Referee#2, whereafter to Referee#3. If we have managed to reply satisfactorily all the concerns and suggestions of all the three Referees, we would like to suggest as the next step to prepare our major revised version of the manuscript for the consideration of all the three Referees, including all the changes suggested in our three replies. The language check will be made only to the final revised version of the manuscript.

Sincerely,
Outi Meinander, on the behalf of the co-authors